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ABSTRACT

Predictions are made based on a study of developments in computer integrated manufacturing (CIM) regarding how they will have an impact on employment, skills needed by Illinois aspirants to manufacturing employment, and the training modes that can be employed most effectively. The report first discusses economic benefits in terms of cost and time reduction in both design and production phases and sales benefits of computer-aided design and computer-aided manufacturing (CAD/CAM). Tables are provided that present total projections, projections by industry and occupation, and anticipated growth rates for employment of engineering technicians who will use CAD/CAM systems. Training needs and skill-level needs of workers from top management to entry-level manufacturing workers are described. An orientation to the new technology at the secondary level is recommended that involves actual, hands-on experience. Titles and brief abstracts of a series of six videotapes concerning effective mass distribution of orientation information are provided. Six units of a CIM orientation course with brief unit descriptions are then proposed. Options are listed for a proposed orientation course utilization spectrum. (Appendixes include a list of equipment items and sources essential to create a mini CIM or CAD/CAM lab.) (YLB)

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CAD/CAM Program Development Study

Project Report

Prepared by

Program Management Associates
Springfield, Illinois

U.S. DEPARTMENT OF EDUCATION
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CAD/CAM Program Development Study
Project Report

INTRODUCTION

This project addressed the need by the vocational educators of the State of Illinois to know the precise nature of impending developments in Computer Integrated Manufacturing. It became apparent in the 1970's that the marriage of the computer with engineering, manufacturing, quality control, material handling, inventory control and product shipping was about to become a reality. Illinois companies such as Motorola and Caterpillar had already begun to experiment with actual implementation of new technology in this area, and early report returns promised astounding possibilities.

This challenged Illinois vocational educators to determine what would happen, when it might happen, how it would impact employment, what skills would be needed by Illinois aspirants to manufacturing employment, and which training modes could be employed most effectively. Soon this activity revealed the need for an analysis and assessment which was not readily available from existing sources, and a procedure to orient Illinois vocational education students to the dramatic changes likely to occur in American manufacturing.

Program Management Associates has undertaken these challenges with the assistance of consultants, corporate and institutional advisory committees, and many helpful individuals in vocational education and manufacturing. The process of predicting the pace of change in new plant investment, employment growth, and technology implementation is an imprecise art, but one which must be attempted to foster the program reassessment needed to assure employment continuity for those who will be educated for this purpose in the 1980's. The predictions contained in this study are assuredly inaccurate to some degree. Probably they will prove to be low - if the relative leadership position of the United States in the global economic structure is to be maintained.

America appears to literally be at the threshold of another industrial revolution. The synergy between the burgeoning development pace in the technologies of robotics and computer graphics may culminate in an astounding transformation before the close of this century.

Between now and 1990 we are likely to witness significant changes in design and manufacturing processes. High-technology electronic capabilities are providing designers and engineers with new opportunities in the creation, development, testing, and production phases of their products. There are significant benefits for those companies ready to take advantage of the opportunities presented by computer-aided design (CAD) and computer-aided manufacture (CAM). These opportunities stem from the unique nature of CAD/CAM systems. These sophisticated computer hardware and software systems interact with both humans and machines. It is this ability to interact and to receive instantaneous feedback that makes the systems, when combined with robots, capable of astounding productivity.

CAD/CAM systems offer the ability to accept, store, and manage large amounts of complex and often interrelated data, to display and flexibly manipulate color graphics and symbols in both two and three dimensions, to readily convert data between digital and graphic forms, and to simulate and model stress situations for test and analysis purposes. Furthermore, the information developed using CAD/CAM systems can be accepted readily by manufacturing systems such as numerically controlled machines, programmed tools, automated material handling systems, etc.

OPPORTUNITIES AND PAST DEVELOPMENT PACE

CAD/CAM systems offer economic benefits in terms of cost and time reduction in both design and production phases. In addition, sales benefits accrue to suppliers that can provide interactive CAD/CAM links with their customers.

Computer-aided design enables manufacturers to:

. Reduce the weeks and months allotted for design time to hours and days
. Reduce errors and defects caused by oversight or lack of attention

- Reduce the amount of documentation and paperwork necessary
- Increase flexibility and variations in products
- Increase reliability through test simulation, and reduce recalls and liability claims.

Computer-aided manufacturing offers the ability to:

- Reduce or hold constant the manufacturing costs
- Reduce the number of parts and processes through standardization
- Reduce costly inventory levels, often as much as 50% or more
- Increase the performance and efficiency of the manufacturing process
- Improve documentation of previous work.

With a stronger link between customer and vendor, design data can be instantaneously exchanged between suppliers and customers which permits more interactive planning of designs.

The factors that will encourage utilization of CAD/CAM systems are technological, economic, sociological, and political. Application of microelectronic developments to design and engineering problems has made these innovative computer systems possible. Those major industries which have utilized CAD/CAM systems have found them extremely successful and beneficial. Many established industries such as aircraft, automotive, and electronics were initially drawn to CAD/CAM because they faced the threat of sagging productivity, increased inflation, increased competition, and shortages of qualified design engineers. Now the application of CAD/CAM is rapidly spreading to wider industry segments, and to subcontract manufacturers with as few as 10-20 employees.

In 1970, America contained approximately 50 CAD/CAM systems, incorporating 200 work stations. By 1980 this had grown to approximately 4,000 systems, incorporating more than 12,000 work stations. The continuing development is predicted to reach the level of 50,000 systems and 200,000 work stations by 1990 and then to reach a saturation level of 200,000 systems in the next century.

PROJECTED FUTURE DEVELOPMENT & TRAINING NEEDS

Virtually all manufacturers, educators and professional associations involved with CAD/CAM predict that more than 90% of all industrial design and drafting will be done on computer terminals by 1990. The demise of

the hand-adjusted machine tool is expected to follow immediately thereafter, along with the installation of totally automated warehouses, material handling systems and fabrication devices.

These predictions presume the necessity to re-train virtually all of the nation's existing Engineering Technicians, which total 690,000-700,000 in number. It also implies the need for a radical departure in the training approach for the additional 381,000 technicians which are projected for entry into the workforce by 1990. Not counting the preparation of those who will maintain the thousands of robots and material control systems, CAD/CAM training needs for those who will utilize the systems, alongside the nation's engineers, will apparently be presented by more than 1 million persons across the nation.

The following tables present total projections, projections by industry and occupation, and anticipated growth rates for employment of Engineering Technicians who will use CAD/CAM systems. Note: These projections assume the development of a substantial economic recovery.

Projected Engineering Technician
Employment Growth (1978-1990) by Occupation

Occupation	1978 Employment	1990 Employment	% Change
Drafters	293,000	446,000	+52.2
Electrical & Electronic Tech.	319,000	512,000	+60.2
Industrial Engineering Tech.	31,000	44,000	+41.3
Mechanical Engineering Tech.	45,000	67,000	+49.7
Total	688,000	1,069,000	

SOURCE: Bureau of Labor Statistics, U.S. Department of Labor

Projected Engineering Technician
Employment (1990) by Industry & Occupation

Industry	Drafters	E & E Techs	IE Techs	ME Techs
Mining	6,900 (1.5%)	3,070 (.6%)	180 (.4%)	400 (.6%)
Construction	34,780 (7.8%)	11,780 (2.3%)	0 (0%)	0 (0%)
Manufacturing	179,290 (40.2%)	245,250 (47.9%)	35,200 (80.0%)	45,760 (68.3%)

Industry	Drafters	E & E Techs	IE Techs	ME Techs
Communications	8,020 (1.8%)	63,000 (12.3%)	300 (.7%)	1,670 (2.5%)
Utilities	11,150 (2.5%)	11,260 (2.2%)	200 (.5%)	340 (.5%)
Transportation	6,250 (1.4%)	3,580 (.7%)	200 (.5%)	1,070 (1.6%)
Wholesale & Retail Trade	14,270 (3.2%)	21,500 (4.2%)	1,940 (4.4%)	2,890 (4.3%)
Services	151,640 (34.0%)	80,380 (15.7%)	3,170 (7.2%)	8,440 (12.6%)
Government	33,900 (7.6%)	72,200 (14.1%)	2,770 (6.3%)	6,430 (9.6%)

SOURCE: Bureau of Labor Statistics, U. S. Department of Labor

Predictions by those with whom we have consulted, at numerous companies and educational institutions,tend to agree at two points:

1. CAD/CAM and robotics will not reduce America's manufacturing and production-related employment levels. While the ranks of the assembly line workers and the machine operators will be severely reduced, the growth of other employment categories will compensate for the reductions.
2. No new employment categories of major significance will be created. A new worker classification (CAD/CAM Technician) will not emerge. CAD/CAM will simply become the standard work tool of engineers, drafters, engineering techs, and many of the machinists who survive the cutbacks in this classification. The classifications of computer repair person, robot maintenance person, etc. are already existing. These and others will be dramatically expanded.

The projection figures noted above do not include the vast needs for training in repair skills. Presently this training is provided primarily by manufacturers, and it is anticipated that assistance in this pursuit will also be needed in the decades ahead. The figures also avoid projections on the impact of laser technology, the burgeoning use of bar code readers and the combination of these developments with computerized control techniques. Those persons involved in warehouse operations, quality control, production planning and inventory control, purchasing and scheduling may also present needs for re-training in new approaches. These training

needs could easily double or triple the level indicated by those engaged in the classical technology pursuits noted above.

The successful manufacturing plant of tomorrow will probably utilize an amazing array of automated processes combined with cells of hand-assemblers and a vast corps of technicians. Semi-skilled and unskilled manufacturing employment may drop as much as 90%, as third-world citizens continually displace the traditional American blue-collar worker. The cost of new technology and training will be offset by enormous savings in inventory reduction, product recall avoidance, and efficiency improvements. Companies who attempt to compete in major industries with present methods and management approaches will face the constant threat of failure in the marketplace, and they will change or die.

Even if these projections concerning those involved in computer integrated manufacturing are in error by a significant factor of over-estimation, one can only conclude that a training challenge of monumental proportion lies ahead. It appears relatively certain that 1 million to 3 million persons must be trained or re-trained in new technologies, or their skills will have little marketability by 1990. Many people presently receiving training in drafting, industrial trades and engineering technology will find they must undergo additional re-training or their employment future will be short-lived.

SKILL LEVEL NEED PROJECTIONS

Processes which are assigned to the various categories of manufacturing technologists will be changing constantly over the coming decades. Engineers are presently engaged in system programming, and even in maintenance and repair tasks, because the procedures of CAD/CAM and other computer integration activities are still new. As these technologies mature, engineers will withdraw from set-up and maintenance activities and technologists will perform most tasks beyond design and development stages. On an opposing note, design terminals which are now used primarily by drafters will also come to be placed on the desk of many engineers. As the cost of computer-aided engineering hardware drops, original design concepts will be roughed out on terminals and will be withdrawn from the data base by drafters and technicians for further development.

Machine operators will commonly cease to perform hand control functions, and must be trained to program robots and automated material handling lines on the plant floor. They will also be challenged to learn to communicate in automation terminology, as the machines they observe are increasingly programmed by engineering or production control persons in remote locations. They will no longer turn a crank to change a machine feed or speed, but will be required to instruct someone else on a needed program change.

Millions of people...from top management to entry-level manufacturing workers...must be trained to speak computer.

These needs portend a wide range of skill level development, along with those in repair and ancillary procedure fields. None of them encroach on the traditional turf of design and development requiring the training and certification of the engineer or the architect. Again it will be primarily a case of need to acquire skills to use new tools and a new language in existing employment categories. The basic ground rules of division of responsibility need not change, and probably will not change dramatically. People will simply be required to perform existing jobs with different tools, using skills which are currently non-existent.

The challenge ahead involves that of training the vast majority of American workers to program automated devices and communicate in automation terminology. The need for present levels of knowledge, involving the proper set-up of a business letter, a machine tool or an air conditioning system, will not diminish. The automation factor will simply become an add-on need for additional skills and knowledge.

The direction in vocational education will be primarily that of changing and adding, not wholesale replacement of programs. Technicians and secretaries do not need training "upward" or a basic career revision. They must become capable of utilizing a broader range of skills, however, or they will be replaced by counterparts who are prepared to do the old jobs in new ways.

This appears to suggest minimal need for new programs in the broad menu already offered in vocational education's realm. It also seems that function levels will not be escalated in most career specialties. New sub-specialties in categories must certainly be created, but no sweeping structural revisions seem to be in order.

The great challenges are those of adding and updating equipment, new ways of thinking and talking, faculty response to the re-definition of many work approaches, and the addition of yet more skill subjects to crowded curricula. One observer suggested, "Electronic drafters will still do the same job, but they will do it four times as fast after five years of training by a 'renaissance man'." This does not portend four-year associate degree programs; it simply means a phenomenal task lies ahead in re-training and continued education. Many technicians graduating today will find that a brief respite must be followed by several more years of formal and on-the-job training.

Donald Frey, Board Chairman of Bell & Howell Co., summed up the challenge as follows: "Unless we begin now to prepare these young people for the jobs of the future, we will have a glut of chronically unemployed and underemployed workers...our curriculum planners must recognize that neither traditional vocational education nor liberal-arts programs are providing the career preparation our students need for the jobs of the future." (SOURCE: "Industry Week", February 7, 1983)

THE ORIENTATION CHALLENGE

Experts consulted in this study frequently express fears that most of the vocational students in industrial study areas are totally unprepared for the transformation which will sweep across American industry in the 80's and 90's. Many are unfamiliar with computer operation techniques and the vocabulary of computer integrated manufacturing. Few are reportedly able to demonstrate an understanding of the procedural changes which will be wrought in the performance of so many jobs.

It is universally agreed that an orientation to this new technology should begin at the secondary level, or at the very latest, by the

first year of post-secondary study. While students must still learn the basic fundamentals of design, drafting, machine operation, etc., and may do so through traditional hand operations, it is essential that they become aware of the changes and challenges which lie ahead. The drafter or machinist who cannot complete the transition will be in a severe job market disadvantage within 10 years.

The better educational programs will begin this transition by 1985, and launch the vast re-training process for prior graduates and other existing workers simultaneously.

The ideal orientation will involve actual, hands-on experience in which students execute simple designs on computer terminals, program simple robots and/or material handling devices, and program numerical control machines to execute the production of the designed pieces. Complements of miniature bench-top equipment can be acquired with a modest investment, as the bill of material recommendations in Appendix I indicate. This will suffice in many programs, as it will undoubtedly not be practical to provide full-blown CAD/CAM instruction in every AVC and community college in Illinois.

Prior to these hands-on activities it is necessary to provide students an overview of computer integrated manufacturing in some manner, or they experience great difficulty in relating their experience to reality. Instructors in established programs which offer exposure to comprehensive equipment with full-size capabilities have indicated that considerable difficulty exists at the earliest point of orientation. Students are severely limited by old perceptions of reality in industrial plants and old production vocabulary. Overcoming these limitations in the classroom is quite difficult, and travel to modern plants incorporating CAD/CAM techniques is often impractical.

A means is therefore needed to expose thousands of students to the coming transformation, and to the basic operations of computer integrated manufacturing. To be effective this must involve the sights and sounds of actual operations - as only seeing is believing.

For this purpose it is recommended that a series of six 28-minute videotapes be produced. These can be reproduced and distributed economically, or they can be recorded off the air by local institutions when they are broadcast by educational TV stations throughout the state. There is certainly no more economical way to achieve the needed mass distribution of this information. These should be planned sequentially to take the student from the American manufacturing plant as it exists today to the factory of tomorrow. Procedural changes in this arena will be occurring almost daily, as new technology develops and existing hardware and software drop in price. This mandates the series' direction away from the minutia of existing processes, as this coverage would be wrong before the production was complete and broadcast was even scheduled. There are some basic elements, however, which are unlikely to change within this century.

These basic elements which should be illustrated are:

1. The macro-processes and vocabulary of automation
2. The process of design via computer terminal
3. The adjustment of machine tools with controlled step motors
4. The use of robots in part manipulation and production procedures
5. Automated material handling, warehousing & shipping
6. Data base integration of design, production, planning, scheduling, purchasing, accounting and inventory control.

The titles for the six presentations and a brief abstract of content might be somewhat as follows:

1. The Factory of the Future

   Begins with a quick review of typical American manufacturing processes, the productivity challenges posed by foreign competition and labor, and moves to the solution of the automated factory. Explains the basic procedures to be covered in subsequent videotapes, and interweaves a short primer on the vocabulary of automation.

2. Computer Aided Design

   Shows how virtually all drafting functions can be done on computer terminals, how the calculations will be automatically generated, and how hard-copy prints are produced. Will explain

how efficiencies occur, how the data base provides testing support, and will interweave orientation to the CAD vocabulary.

3. Computer Aided Manufacturing
   Shows how computerized numerical control machines execute commands and then grind, stamp, bore, drill, turn, face and finish. Explains machine adjustment with step motors, programmed on the machine or remotely, and why they are replacing the hand-turned crank.
4. Robotics
   Shows what robots can do, and how they fit into the manufacturing process. Covers all robotics operations such as part manipulation, painting, welding & grinding, and the automated inspection station. Includes emphasis upon productivity improvement and shows the role of employees in programming, inspection, repair, setup and change-over functions.
5. Flexible Manufacturing Systems
   Shows how old synchronous, in-line material flow caused inventory waste and made small-batch production impossible. Introduces automated, non-synchronous workflow, automated vehicle guidance, just-in-time scheduling, automated material handling, in-floor towlines, and automated high-density storage. Explains the necessity for the workflow system with flexibility of work-station selection, and shows how robots load pallets and trucks.
6. Computer Integrated Manufacturing
   Shows how the same (or similar) database which provided instantaneous design calculations can also provide control functions for the entire operation. Explains automated planning, production scheduling, purchasing, inventory control and cost accounting. Concludes with the explanation that old jobs will be done in new ways or replaced by new jobs, points up skills needed, and closes on a positive commentary regarding America's industrial comeback through automation.

Proposed CIM Orientation Course

Local agencies and institutions which desire to present a CIM orientation course would be rewarded in their efforts to do so. This activity faces two obvious challenges. First is the rapid pace of change in this technology. New procedures in areas such as distributed numerical control will unfold rapidly, and critics will continue the old paean which chides vocational education for being behind the times and out of sync with reality in the multi-million-dollar industrial installation. The second challenge is that of acquiring and maintaining the necessary equipment complement to provide relevant, hands-on experience. Both challenges can be met, in our opinion, to a degree sufficient to make the effort definitely worthwhile.

The videotapes proposed above would serve a dual purpose. Though designed to make a six-session, continuous course for TV or cassette viewing, the materials should also provide excellent introductory sessions in a six-unit course of greater length. Such a course should be a laboratory course, utilizing a Mini-CIM lab and full-scale CAD work stations and/or manufacturing equipment as it is available. The proposed units of the course, with brief unit descriptions would be as follows:

UNIT I - The Factory of the Future

Utilizes the proposed videotape, lectures and assigned reading to enable students to understand the macro-processes which will bring the transformation now often called "the new industrial revolution". This unit would also provide a grounding for students in the vocabulary of automation, CAD/CAM, and flexible manufacturing systems.

UNIT II- Computer Aided Design

Provides students with hands-on experience in executing simple designs on a computer terminal. The basic procedures of design using low-resolution terminals and simple software (Apple II and Apple Logo, etc.) are similar to those used in larger systems, and the major differences can be illustrated with the videotape, lectures and hand-out materials.

UNIT III - Computer Aided Manufacturing

Provides students with hands-on experience in programming a computerized numerical control machine, using free-standing units and/or CNC machines and controllers interfaced with a microprocessor (Apple II, etc.). Also provides experience in retro-fitting miniature or full scale machine tools with step motor controls. Support with videotape, lectures, hand-outs.

UNIT IV - Robotics

Provides students with hands-on experience in programming, maintaining, assembling and repairing robotic devices. While the smaller units will differ dramatically from large industrial robots, operational principles are similar. Differences in scale and complexity will be illustrated by videotape and hand-outs.

UNIT V - Flexible Manufacturing Systems

The videotape and lectures will provide students with an introduction to flexible, non-synchronous workflow, automated storage and retrieval, and modern material handling systems. This is a key activity in high productivity gain, and a radical departure from existing plant layout methods, so the promotion of basic understanding is essential. Field trips to nearby installations would be desirable where this is possible.

UNIT VI - Computer Integration

The videotape, diagrams, lectures and hand-out materials will provide students with a basic understanding of the use of data bases. Integration of design data with control operations throughout the various departments in the company would also be explained. This unit would explain how computer integration will achieve tremendous savings in quality testing and control, inventory reduction and scheduling. It will also show students how batch production will foster consumer choice response and sales gains. This unit should also show how CIM and CAD/CAM will utilize people, dispelling notions that automation will bring mass reductions of gross manufacturing employment.

ORIENTATION COURSE UTILIZATION

As Illinois, along with most other states, is engaged in a catch-up process, it is important to infuse this orientation into vocational programs as soon as possible. This mandates the use of videotapes, orientation discussions and materials in some advanced courses already underway at the community college level. These advanced students are already beyond the ideal starting point, yet they still need this orientation. Without it many of them are surely harboring illusions about the future marketability of the skills they have acquired.

A proposed utilization spectrum would include the following options:

A. Secondary Level - The videotapes and companion materials should be incorporated into secondary-level courses in subjects such as Drafting, Manufacturing Processes, Business Education, etc.

B. Area Vocational Center - The AVC should incorporate the CIM Orientation as noted above. Those AVC agencies with community college affiliations should also be capable of presenting a laboratory course providing a fuller understanding and hands-on experience.

C. Community College - Community colleges offering technical, design and manufacturing trades programs will, in some cases, be teaching students at full-scale CAD work stations and with production-scale robots and CNC equipment. These institutions may wish to incorporate an orientation into early courses in these sequences to give students an overview. In institutions where this equipment is not available, a full-year laboratory course in CIM orientation should be presented. Its objective would be that of actually training students to execute simple designs on a computer terminal, and to program CNC machines to execute the designs.

D. Community College (Advanced) - As noted above, a CIM orientation should be infused into advanced course sequences where none has been provided in previous study. All students graduating from drafting, design, machine trades, engineering technology and related courses should receive this orientation in some manner.

The Equipment Bill of Materials, provided as Appendix I, has provided a guide to items needed in the creation of a Mini-CIM laboratory. Those entities which are prepared to utilize full scale equipment will already know the items desired and the vendors. The assembly of the Mini-CIM laboratory should involve the data processing, electronics, and manufacturing trades faculty (and students) in any local education agency. The materials listed will not present an assembly complexity problem beyond the capabilities of this group.

In some institutions, partnerships have been formed between undergraduate institutions and universities. Graduate student projects have provided software packages, controllers, miniature CNC machines, robots, and automated material handling lines. Prototypes have then been duplicated by undergraduate project activity, and complete laboratories have been produced at nominal costs.

Most institutions and local agencies will prefer to buy and assemble the laboratory, using complete, assembled component items as listed. Industrial sponsors are available, as is any assistance needed in setup. Very few educational entities are excluded from this march of industrial progress if determination and resourcefulness are applied to the task. The ideal time to begin planning for this activity has already passed. Institutions which begin now are already in a catch-up mode, and those which resist or delay will be providing vocational programs with significant limitations.

RESOURCES FOR TRAINING MATERIALS

In a recent series of speeches, and an article in INDUSTRY WEEK, Donald Frey, Board Chairman of Bell & Howell Co., has laid a significant challenge at the door of American industry. Mr. Frey has stated, "Knowledge will be our most precious resource, and a better educated workforce - at every level of the productive process - will be the prerequisite for future economic vitality. We are not meeting this challenge." He then specifically urges industry to:

1. Cooperate in the development of programs to train dislocated workers, untrained and unemployed young people.
2. Increase direct corporate grants to colleges and schools.
3. Provide equipment for school laboratories.

Business leaders today have the foresight to realize that budgetary restraints on public education entities render them incapable of responding to the vast training needs ahead...unless significant external assistance is provided.

This realization is the light at the tunnel's end for resourceful agencies needing to generate Mini-CIM laboratories. Their equipment needs are matched by tremendous training capability needs in industry, and fruitful partnerships can be readily created in many areas. Mini-CIM laboratories can be established for less than $10,000. Full scale CAD/CAM installations cost more than $100,000 at this time, with costs scaling upwards of $1 million if even a modest level of sophistication is sought. Surprisingly, the solicitation of funds even at this level has been routinely successful (often received as equipment donations) when the institution asking has been prepared to effectively utilize the laboratories.

The crucial ingredient for success in building labs with external support has been that of "quid pro quo," as manufacturing firms are not regularly willing to make significant donations on the basis of pure altruism. Creativity in this realm has played a key role when success has appeared to "come easy."

Appendix I

EQUIPMENT BILL OF MATERIALS

Introduction

The creation of a Mini CIM Lab or Mini CAD/CAM Lab will be extremely valuable for every educational agency and institution which provides programs in design, drafting, or any realm of industrial trades. Without exposure to computer technique the student is virtually heading into an employment wasteland.

The proposed videotapes can begin the essential cognition process, revising expectations and fostering awareness, along with the generation of a non-tactile level of understanding. The full cycle of effective training, however, must involve hands-on experience. Listed below are the equipment items and sources which are essential to create the environment for this experience.

The Mini CIM Lab

The functional CIM Lab must enable students to create simple designs on the computer terminal. Then it must enable them to experience the process of directing, via computer terminal or programming keyboard, a machine tool to produce the designed part. It must also then provide access to robotic devices which can manipulate, stack, assemble or process work in some manner.

These procedures require the following component items:

1. A microprocessor such as Apple, TRS-80, etc.
2. A software program which enables the computer to produce graphic designs, such as Apple Logo.
3. A controller which will accept commands from a computer and translate these into actuation impulses for stepper motors.

4. One or more machine tools, produced or retro-fitted with stepper motor controls, which can execute the commands.
5. One or more programmable robotic devices which can move or manipulate parts upon command.

These labs can be acquired, complete, for less than $15,000, including all items noted above. Many institutions will choose to train and use industrial technology students to retro-fit machine tools with stepper motors, thereby "manufacturing" a computerized numeric control production machine. This is excellent training, as much of this activity will occur in industry in the coming decade.

Some agencies and institutions will undoubtedly choose to acquire a more complete miniature plant layout, complete with material handling and inventory control devices. Many components can be fabricated once the basic technology is mastered, but the following equipment items are available, off-the-shelf, at prices indicated (March 1983) in the following section. In an industrial area, equipment vendors and/or local manufacturers are most willing to assist the enterprising educator. On a purely charitable basis, or certainly in exchange for training assistance, a vast array of guidance and equipment donations can be obtained.

Bill of Materials

A. Microprocessors

Apple II+, TRS-80 and comparable micros are commonly available in schools throughout the state. These may be acquired through consortia or by direct purchase from local dealers.

B. Software (Computer Graphics)

Graphics programs, such as Apple Logo, are available from Logo Computer Systems, Inc. through local dealers. In Illinois these programs are available at $175 from:

microPOWER Computer Systems, Ltd.
923 South Fifth Street
Springfield, IL 62703

C. CNC Controllers

An intelligent stepper motor control system, for miniature machine tools, is available at $1,795. This system will operate up to (3) three stepper motors, up to 5-amp per phase motor size, including bus expanders for plug-in connection to computers, 3-axis intelligent controller, motor amplifiers, power supplies, connectors and resistors for motors. This model CY 3+3 is compatible with computers with 48K RAM memory and one disk drive. The controller includes one diskette of software.

Also available for a larger system is a System 2 controller, which will control up to (6) six stepper motors, up to 3.6 amp per phase motor size, at a price of $2,795 (March 1983).

The vendor, possibly operating as a single source, is:

Robotic Synergy, Inc.
1336 South 1100 East
Salt Lake City, Utah 84105

D. Machine Tools

Numerous miniature lathes, drills, and milling machines are marketed, which utilize motors requiring no more than 3.6 amp - 5 amp per phase power source. Camera lathes, when available, can often be obtained used for less than $1,000. Small production lathes are also available within this price range, as well as milling machines.

In most cases these are not available with stepper motor controls, but can be easily retro-fitted with stepper motors.

Vendors recommended are:

Central Purchasing, Inc.
7110 Case Avenue
North Hollywood, CA 91605

Midwest Edusystems, Inc.
2701 Grand Avenue
Galesburg, IL 61401

Robotic Synergy, Inc.
1336 South 1100 East
Salt Lake City, Utah 84105

A high-quality programmable CNC device, complete with its own microprocessor and controller is also available at a price of $8,500-$8,900 (determined by accessories ordered). This training lathe is complete and free-standing, with 3-axis capability, instructor's package and training manual. It would be a valuable addition to train students who were not involved with design, as an expansion to the basic lab set-up proposed. The vendor is:

EMCO-MAIER CORP.
2050 Fairwood Avenue
Columbus, OH 43207

E. Programmable Robots

Microbot - This low-cost, self-contained device simulates industrial robot operation. Its 5-axis movement and "intelligent" gripper can be programmed from its own control device, or from the keyboard of an Apple II or TRS-80 (with interface accessories). The TeachMover 5 model is available at $2,395 from:

Allison Associates
P. O. Box 313
Troy, Michigan 48099

Rhino XR-1 - This robot is produced for self-control or by a host computer through standard RS-232C interface parts. Its 6-axis operation and wider accessory range make it the "device of choice" to many instructors. It is built with all components exposed, which facilitates understanding and repair instruction. It is available at $2,500-$3,000 (determined by accessories ordered) from:

Midwest Edusystems
2701 Grand Avenue
Galesburg, Illinois 61401

HERO I - This training robot is mobile, complete with voice, sensors and a robotics training course. It is controlled by its own microprocessor, carries electronic sensors to detect light, sound, motion, and obstructions in its path, and features

a voice which simulates speech and sound effects. Its 5-axis arm is capable of gripping and lifting only very light payloads (5 oz. and 16 oz. respectively). This device is available in kit form at a price of $1,500 or factory assembled and tested for $2,500 from:

Midwest Edusystems, Inc.
2701 Grand Avenue
Galesburg, Illinois 61401

Other Options

Many other devices are available, and the range of those which can be locally devised is obviously limitless. Those noted above have been recommended for consideration after survey inquiries with users have indicated their quality and usefulness is significant.

The educational institution which has established a clear leadership in this realm is Brigham Young University. Dell K. Allen, Ph.D., operates an effective mini-lab which interested educators are encouraged to inspect. His advice would be valuable to any colleague who is making equipment selections.

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